A STUDY OF THE EFFECT OF WARM-UP ON CERTAIN PHYSIOLOGICAL PARAMETERS DURING EXERCISE AND RECOVERY

by

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CHAPTER I

INTRODUCTION

Studies which have been done in the past several years have indicated a lack of agreement on the part of researchers as to the effect of warm-up on exercise. Several investigators have reported that performance was improved by the use of a warm-up (2,3,10,11) while others have reported that warming up prior to testing did not significantly improve performance (6,7,9,13,14). For the most part, these studies have been concerned with the effects of a warm-up on performance of some specified motor skill such as swimming, running, softball throwing, and jumping.

Relative to differences in physiologic responses, two studies were reviewed. Howard, Blyth and Thorten's (5) investigation concerning the effects of warm-up on the heart rate during exercise and unpublished data by Elbel and Mikols (4) which were secured following passive or active warm-up. Data were obtained on the following: heart rate, ventilation, oxygen uptake and the amount of exhaled carbon dioxide.

Athletic coaches and physical education teachers have for many years considered the value of warm-up prior to vigorous activity. However, a few athletes and coaches are inclined to question the value of extensive preliminary active warm-up, feeling that with strenuous exercise the athlete may have already exhausted a needed part of his energy when the time arrives for the major performance. Warm-up may, in fact, be nothing more than actual practice or becoming acquainted with the techniques peculiar to a particular activity. Skubic and Hodgkins (14) found general improvement with practice in the softball throw for distance; a ride on a stationary bicycle, and basketball free throwing whether preceded by no warm-up, general warm-up or related warm-up. On the other hand Pacheco (11) after conducting a study on jumping performance, found that increasing the amount of preliminary exercise in the form of deep knee bends and running, was reflected by improved performance.

Lotter (7) concluded that warm-up had no effect on arm movement, but found that on the second of two crank-tests, the results were improved over the first tests. He felt that the improvement was the result of a practice effort.

Although researchers have been concerned with the effects of warm-up prior to vigorous performance, it seems that much more attention has been directed toward the different kinds of warm-up on performance rather than upon the physiological changes which might have taken place within the individual during warm-up or without warm-up.

Statement of the Problem

The purpose of this study was to determine the possible changes in certain physiological parameters during exercise and recovery from exercise carried on with or without a previous warm-up period. More specifically the following parameters were studied:

1. Heart rate
2. Oxygen uptake
3. Total ventilation
4. Breathing frequency
5. Carbon dioxide expired
6. Oxygen uptake per meter squared body surface area

Limitations of the Study

This study was limited to 10 volunteer male university subjects, ages 18 through 23 years who had a minimal amount of experience concerning running on the treadmill. While running on the treadmill, the subject was fitted with a facemask and chest electrodes and was running at a constant speed. These factors are, of course, unnatural and should be taken into consideration.

The oxygen intake values were derived from percentage subtraction, using inspired ventilation only. This would give general but not specific values. This may be considered a limitation of the study. The formula used for determining oxygen utilized in liters/minute is as follows:

> Per cent of oxygen in room air – per cent in expired air x liters/minute-volume (STPD)

It will be noted that no data were gathered while the subjects were immersed in the tank during the passive warm-up period. This fact should also be considered a limitation.

Significance of the Study

A considerable amount of investigation has been done on the effects of no warm-up, passive warm-up and active warm-up in relation to performance. It would seem that if one method of warm-up is superior to the others, the differences would be evident in the physiological measurements obtained under like conditions. Two of the above mentioned conditions, no warm-up, and a form of passive warm-up were used in this investigation in order to determine whether there were significant mean differences.

Some athletic coaches and physical education teachers, as well as some athletes, feel that strenuous active warm-up prior to the majority activity is important as well as beneficial. On the other hand there are those who feel that indulging in strenuous active warm-up prior to a major activity may, in fact, tire the individual so as to hinder his best performance during the activity.

Definitions and Abbreviations

1. Cold Condition - no form of active warm-up (related or unrelated) or any form of passive warm-up.
2. l/minute - liters per minute.
3. M^2BSA - Square meters of body surface area.
4. STPD - Standard temperature (degree Centigrade) and barometric pressure (760 mm Hg) dry.
5. Warm-up - Warm-up as defined for this study is an unrelated passive warm-up consisting of the subject being immersed in a tank of water for 10 minutes at 98° F.

CHAPTER II

REVIEW OF THE LITERATURE

Karpovich and Hale (6) performed three different series of experiments on warm-up. Seven track athletes each ran 440-yards after deep massage, digital stroking and exercise. Each of five men ran 440-yards without warm-up after digital stroking. Three subjects participated in sprint rides on the bicycle ergometer after preliminary exercise and without warming up. They concluded that none of the warming devices improved times in running 440 yards or improved performance on the bicycle ergometer.

Supporting Karpovich and Hale was a study completed by Skubic and Hodgkins (14), in which 31 women physical education majors were subjects. The women each performed three tests: one speed test during which each rode equivalent to one-tenth of a mile on a bicycle ergometer; one strength test in which each threw a softball for maximum distance; and a test for accuracy which involved scoring as many basketball free throws out of 10 attempts as possible. Tests were performed under the following conditions: no warm-up, one which was preceded by a general warm-up, and one which was preceded by a warm-up related to the test activity. Their results showed general improvement, but no significant differences in the scores made in relation to the three types of warm-up procedures. They also reported that no injuries resulted nor did the subjects report muscular soreness during the testing period.

Pacheco (11) tested 10 experienced college subjects, nine men and one woman, in five or more groups of six trials on a standardized vertical jump under each of four conditions. Compared to the non-warm-up control group, warm-up with deep knee bends improved performance 2.88 per cent. Isometric stretching prior to the activity improved performance 4.99 per cent. Warm-up by stationary running improved performance 7.80 per cent. All these differences were statistically significant (.01 level).

In a second experiment Pacheco used 50 college men as subjects. He found that performance in the vertical jump improved 3.27 per cent after preliminary knee bends. The increased mean performance in this test was highly significant.

Testing the importance of warming up before competitive swimming, Carlile (2) obtained results which showed improvement in performance in swimming 220 yards of 1.5 per cent following hot showers of eight-minute duration. Also, 10 swimmers in 230 trials with various strokes, showed an improvement of one per cent in 40-yard time-trials when the swims were preceded by eight-minute hot shower baths. A statistical consideration of the group-data showed the difference in swimming speed between control and preheated swims to be highly significant in favor of the latter.

Michael, Skubic, and Rochelle (10) used 77 college men as subjects in throwing a 12-inch softball three times for distance with no preliminary warm-up; with a preliminary five-minute non-related general warm-up; and with a preliminary five-minute related throwing warm-up. The results revealed that both types of warm-ups resulted in significantly longer throws and that the amount of time spent in warming up and the strenuousness of the warm-up appeared to be factors involved in improving the throwing distance.

Mathews and Snyder (9), after studying the 440-yard performance of 50 high school boys after moderate warm-up consisting of jogging, stretching, and sprinting, found that performance was better after no warm-up although the differences in means were not statistically significant.

To study the effects of warm-up, DeVries (3) used the 100-yard swim for speed as a standard measure. He found in considering all swimmers as a group, regardless of stroke, warming up by swimming 500 yards slowly prior to strenuous performance was effective in significantly reducing the subsequent 100-yard time-trial. Whereas when the warm-up prior to strenuous performance was unrelated (hot showers, massage, calisthenics) there was no significant improvement in the 100-yard swim time.

Thompson (16) used speed-swimming over 30 yards; swimming endurance; accuracy in basketball foul shooting and bowling, while Lotter (7) observed the effect of general warm-up on endurance as indicated by turning a crank for a period of four-minutes recovery. In each instance it was concluded that generalized exercise warm-up had little or no positive effect upon performance.

Benjamin and Peyser (1) and Howard, Blythe and Thorten (5) conducted studies concerning the effect of active and passive warm-up on heart rate. These investigators concluded that there was no significant mean difference in heart rate during activity after active or passive warm-up.

Elbel and Mikols (4) tested 17 university men who were in better-than-average physical condition on the effects of active and passive warm-up. The activity was running on a treadmill for 10 minutes at eight miles per hour followed by a 10-minute recovery period. The active warm-up consisted of walking on the treadmill for three minutes at four miles per hour, jogging for four minutes at six miles per hour and walking for three minutes at four miles per hour. The passive warm-up consisted of seating the subjects, immersed to their necks, in a tank containing water which was kept at 100° F. for a period of 10 minutes. It was concluded that the means for minute-volume following active warm-ups were significantly larger than those following passive warm-up for the third through the ninth minute of running and for the fourth minute of recovery. While their means for O_2 utilization, expired CO_2, number of respirations, heart rate and respiratory quotient were generally larger following active warm-up, there were no uniform trends in acceptable levels of significance.

As a psychological control Massey, Johnson, and Kramer (8) used hypnosis to prevent their subjects from knowing whether or not they had participated in warm-up. They found no statistically significant mean differences between sprint rides on the bidycle ergometer done with or without warm-up.

Smith and Bozymowski (15) investigated the attitude of college women toward warm-ups and motor performance. An attitude inventory was administered to each of 86 subjects, after which an obstacle race was administered without a warm-up period and again with a three-minute warm-up period. They concluded that the subjects with a more favorable attitude toward warm-up performed significantly better when warm-ups preceded the obstacle race, while those subjects with a less favorable attitude did not improve significantly when warm-ups were given.

CHAPTER III

RESEARCH PROCEDURE

Selection of Subjects

The subjects consisted of 10 university men, ages 18 through 23, who volunteered to participate in the experiment. All of the men were active in either intramural or intercollegiate athletic competition at the time of testing. The means and standard deviations for height, weight, body surface area, heart rate, systolic and diastolic blood pressures and pulse pressures, secured during the instruction period, are shown in Table 1.

Procedure for Exercise Test

The subjects followed the same procedure on each of five consecutive days. The period on one day was used for instruction. On each of two days, the subject performed in the passive warmed-up condition and on each of two days he performed without warm-up. A total of 40 tests were completed, 20 tests while subjects were in the passive warm-up condition, and 20 tests while they were in the non-warm-up condition.

The order of testing of subjects was randomized, but subjects performed in the warm condition and the cold condition on alternate days. At the end of the fifth day the testing cycle was completed. All data were secured within a six-week period.

TABLE 1

MEANS AND STANDARD DEVIATIONS FOR DATA SECURED DURING THE INSTRUCTION PERIOD

Parameters	Means	S.D.
Height (inches)	71.20	2.51
Weight (kilograms)	77.50	9.48
Body Surface Area	1.96	0.14
Pulse		
Reclining	69.05	6.60
Sitting	73.80	9.09
Standing	81.90	9.80
Blood Pressure		
Systolic	119.50	9.93
Diastolic	80.80	8.51
Pulse Pressure	46.40	7.85

Description of Apparatus and Method

For securing heart rate, a standard medical cardiotachometer[1] with a transistorized radio receiver, a frequency filter and a transistorized transmitter,[2] were used. Electrodes were attached

[1]Johnny Walker Tel-EKG Transceiver Model BW-7 Johnny Walker Medical Electronics Instruments, Kansas City, Missouri.

[2]Johnny Walker Medical Electronics Instruments, Kansas City, Missouri.

to the left scapula and the two others were placed at either side of the upper chest. The electrodes were held in place by means of the electrocardiograph chest-straps. A standard electrode paste was applied to insure better conduction of impulses.

The heart rate signals from the transmitter were received by means of a regular FM radio and relayed to the cardiotachometer from which visual readings were made every 30 seconds.

The volume of expired air was measured by means of a large orifice gas meter.[3] An especially constructed large orifice face mask was attached, which in a system involving a two-way low resistance valve allowed the subject to inhale room air which was drawn through the gas meter. Individual gas meter readings were secured each minute.

The number of respirations per minute were secured by means of a thermister in the face masks which was attached to a tel-thermometer.[4] Recordings of the fluctuations caused by the difference in temperature of inspired-expired air were obtained by means of a Varian G-11A recorder.[5]

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[3]Parkinson Cowan Industrial Products, Dolphin, Fitzalen Street, Kennington Road, London, England.

[4]Yellow Springs Instrument Company, Inc., Yellow Springs, Ohio.

[5]Varian Model G-11A Recorder, Varian Associates Recorder Division, 611 Hansen Way, Palo Alto, California.

The per cent of oxygen and per cent of carbon dioxide contained in the expired air were secured by means of a Beckman Oxygen Analyzer[6] and a Beckman Carbon Dioxide Analyzer,[7] respectively. Samples of expired air were collected in a 13-liter spirometer[8] and were then pumped through the analyzers. It should be made clear that the spirometer was used simply as a sample-collecting reservoir and remained intact as a permanent element in the set-up.

For analyses, the minute-by-minute samples were drawn from the spirometer and passed through calcium chloride which served as a drying agent. By the use of a "Y" tube part of the sample passed through a flowmeter and thence through the carbon dioxide analyzer. The other part of the same sample passed through a flowmeter and into the oxygen analyzer. The oxygen readings were secured visually while the carbon dioxide percentages were recorded.

Prior to testing of each subject, the carbon dioxide analyzer was calibrated with a commercially prepared gas and the oxygen analyzer with a known oxygen sample. During that part of each minute when air samples were passing through the analyzers, the expired air was shunted directly into the atmosphere.

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[6]Beckman Model E-2 Oxygen Analyzer, Beckman Instrument Corp., Fullerton, California.

[7]Beckman Model LB-1 Carbon Dioxide Analyzer, Beckman Instrument Corp., Fullerton, California.

[8]Respirometer, Warren E. Collins Incorporated, 555 Huntington Ave., Boston 15, Massachusetts.

At the time the tests were administered, measures were secured on each subject during a five-minute pre-exercise period while seated on a stool on the treadmill; a five-minute exercise period with the subject running at eight miles per hour on the treadmill; and a five-minute recovery period during which time the subject was seated on a stool on the treadmill. The following data were secured: the heart rate, ventilation, per cent O_2 expired, per cent carbon dioxide expired, and the number of respirations per minute.

<u>The Instruction Period</u>

The subject was allowed a preliminary rest period while in a reclining position for at least 15 minutes. During this time the name of the subject and other personal data were recorded. For possible future reference, a six-lead electrocardiogram was secured immediately following the preliminary rest period. Upon completion of the electrocardiogram, the testing procedure was explained to the subject. With the subject in a sitting position the systolic and diastolic blood pressure were then obtained.

The electrodes for telemetering heart rate were then affixed (two on the chest and one below the inferior angle of the left scapula) and while still seated on the stool on the treadmill, a face mask was attached. During the instruction period data were collected with the subject at rest while seated on the treadmill, while running and during recovery.

After the completion of the instruction in treadmill running, the height, to the nearest tenth of an inch and the weight to the nearest one-fourth pound, were recorded. The Du Bois Body Surface Area Chart (as prepared by Boothby and Sandiford) was used for determining the square meter body surface area.

Procedure for Passive Warm-up

Immediately after entering the laboratory, the subject changed to gym shorts and shoes. The subject rested in a reclining position for a period of at least 15 minutes. After the heart rate electrodes were attached and with the subject seated on a stool on the treadmill, the face mask was put in place and the subject rested for a period of five minutes during which time data were recorded (heart rate at 30-second intervals; all other measures at one-minute intervals).

Following the five-minute rest period, the face mask and electrodes were removed and the subject sat immersed to the neck for ten minutes in a tank filled with water which was kept at a constant temperature of 98° F. While in the tank he was seated on an adjustable sling. Upon leaving the tank, two assistants dried the subject and assisted him in putting on his trunks and shoes. Simultaneously, the heart-rate electrodes were attached.

While the subject was standing on the treadmill, the face mask was put in place and the five-minute exercise period was begun. The exercise consisted of running at a speed of eight miles per hour for a period of five minutes. Readings were secured each minute. The elapsed time from leaving the tank to the start of exercise varied from 90 seconds to two minutes. Recovery readings were obtained each minute during the five-minute recovery period while the subject was seated on a stool on the treadmill.

Procedure for Non-Warm-up

The procedure for the non-warm-up phase was the same as for the warm-up except the exercise measures were secured immediately after the five-minute pre-exercise period. The subject ran for a period of five minutes and recovered for five minutes.

Each day the room temperature and barometric pressure were recorded. The per cent of expired O_2, the percent of expired CO_2, and air volume were corrected to STPD/M^2BSA.

Calculation of Data

The following formula was used for determining oxygen utilized/square meter body surface area:

$$\frac{\text{Per cent oxygen in room air} - \text{per cent in expired air} \times \text{liters per minute volume (STPD)}}{M^2\text{BSA}}$$

The amount of carbon dioxide expired/M^2BSA was computed as follows:

$$\frac{\text{Per cent carbon dioxide in expired air} \times \text{liters per minute volume inspired air (STPD)}}{M^2\text{BSA}}$$

The following formula was used for determining per cent heart rate increase:

$$\frac{\text{Heart rate during exercise} - \text{pre-heart rate}}{\text{Pre-exercise heart rate}}$$

The per cent heart rate recovered was computed as follows:

$$\frac{\text{Pre-exercise pulse rate x 100}}{\text{Pulse at X minutes of recovery}}$$

The means and standard deviations were calculated for each test by standard statistical procedure.

To determine a possible significant difference between the performance in the warm condition and the non-warm condition, the following formula was used:

$$t = \sqrt{\frac{(\Sigma D)^2 \times N - 1}{D^2 \times N - (\Sigma D)^2}}$$

Only t values at the .05, .02 or .01 level of significance were considered acceptable. The Table of Significance of t values (as prepared by Garrett) was used for this purpose.

Reliability and Validity

In order to insure the reliability of the oxygen and carbon dioxide measurements, the analyzers were calibrated prior to the testing of each subject. For calibrating the oxygen analyzer 95 per cent content of oxygen was used as follows: Nitrogen was used to bring the adjustment control to zero. After the reading had stabilized at zero, a sample of 95 per cent oxygen was pumped through the analyzer. The dial was then set at 95 per cent and the span-knob was adjusted until the light was centered on the line. This procedure was repeated twice. Then room air was pumped through the analyzer to determine whether the analyzer showed between 20 and 21 per cent. Recalibration was not done if room air readings were correct. Ten per cent, five per cent, and two per cent reference gases were used to calibrate the carbon dioxide analyzer prior to each testing period.

Test-retest procedure for obtaining reliability was not attempted because it was felt that since these were volunteer subjects, additional testing could not be required of them without imposing upon their time and energy.

CHAPTER IV

RESULTS

Prior to testing in the cold condition, the mean pre-exercise heart rate with subjects sitting on a stool on the treadmill was 65.25 beats per minute. During the first minute of running there was an increase of 65.25 beats per minute, exactly doubling the pre-exercise rate. The peak rate was reached during the fifth minute of running (150.66 beats per minute). The increase over pre-exercise level was 85.41 beats or 130.90 per cent (See Table 3).

Immediately prior to passive warm-up, the mean pre-exercise heart rate was found to be 65.80 or 0.55 beats per minute greater than the mean when subjects were in the cold condition. During the first minute of exercise the mean heart rate increased 69.45 beats per minute (to 135.25 beats per minute). As was the case with subjects in the cold condition, the peak increase in heart rate was reached during the fifth minute of running (See Table 3).

Based upon the fact that the t-value (t = 1.31) computed from the difference between the means was not significant, it was concluded that there was no appreciable difference in the mean pre-exercise heart rate when subjects were in the cold condition, as compared to the mean prior to passive warm-up.

The t-values for the difference between the mean heart rates for the first minute of running without warm-up and following passive warm-up was found not to be significant (t = 1.98). In fact, no significant t-values were found for mean differences in the heart rate for any of the five minutes of recovery.

Relative to heart rate during the recovery period, at the conclusion of the first minute following no warm-up the mean rate was 102.50 beats per minute. Following passive warm-up, the mean rate was 101.75 beats per minute. The t-values resulting from the difference between the means (0.01) was not significant. The t-values of 0.18, 0.18, 0.03, and 0.01 for the second through the fifth minute respectively were not significant.

From a physiological standpoint, it is interesting to note that while there were no significant differences between the heart rate means, there were some numerical differences in the per cent of increase in heart rate while subjects were running. At the close of the first minute the rise for no warm-up was 100.00 per cent, reaching 130.89 per cent for the fifth minute. The per cent of increase for the first minute running, the heart rate following passive warm-up was 105.55 per cent and reached the greatest per cent rise at the close of the fifth minute (137.08 per cent). (See Table 3.)

At the conclusion of the fifth minute of recovery when no warm-up preceded the exercise, the per cent recovered (returned to pre-exercise level) was 85.02, while for the same minute in the recovery period when passive warm-up preceded the period of running, the per cent recovered was slightly higher (87.04 per cent). (See Table 3.) Prior to the no warm-up testing period the mean pre-exercise respiratory rate was 16.00. Following the first minute of running there was an increase of 10.32 respirations per minute to 26.22, reaching a peak of 35.89 at the fifth minute of running. The mean pre-exercise respiratory rate while sitting prior to running in the warm condition was 15.80, increasing 8.43, to 24.23 during the first minute of running and reaching a peak of 35.84 during the fifth minute of running. (See Table 4.)

Following running without warm-up, the mean respiratory rate for the first minute of recovery was 24.20, dropping to the lowest point (18.90) at the fifth minute of recovery. The mean respiratory recovery rate for the first minute following running in the warm condition was 25.80 dropping to the lowest point of 19.40 at the fifth minute (Table 4). A t-value of 2.32 for the second minute and one of 2.34 for the third minute of recovery were found to be significant at the .02 level showing a significantly greater return to the pre-exercise level during the second and third minutes of recovery following running without warm-up. The mean pre-exercise oxygen uptake in liters/minute with subjects in the cold condition was 0.35 (Table 2). At one minute of running the mean for oxygen uptake was 1.23 liters/minute, a peak of 3.46 liters was reached at the fifth minute. Prior to running in the warm condition the mean pre-exercise oxygen uptake in liters/minute was identical to that prior to running in the cold condition (0.35), increasing to

1.32 the first minute of running and a peak uptake of 3.65 liters at the fifth minute of running. (See Table 5.)

Based upon the t-values, the mean oxygen uptake was significantly greater for the second (t = 2.10) and fifth minutes (t = 2.52) of running following passive warm-up than was the case when subjects ran without warm-up (Table 2). However, it should be noted that although listed as the .05 level of significance, the t-value for the second minute of running was so near the border line it could be considered of doubtful significance. There were no significant t-values for mean difference for the first (t = 1.45), third (t = 2.02), and fourth (t = 1.01) minutes of running.

The mean liters/minute oxygen uptake for the first minute of recovery following running in the cold condition was 2.30 liters. The smallest mean quantity of oxygen uptake during the recovery period was during the fifth minute (0.56 liters). (See Table 5.)

Following running in the warm condition, the mean oxygen uptake for the first minute was 2.46 liters. The smallest mean reading was obtained for the fifth minute of recovery (0.56 liters). (See Table 5.)

Based upon the fact that there were no significant t-values resulting from the differences between the minute-to-minute recovery means for oxygen uptake in liters/minute, it was concluded that recovery oxygen uptake was relatively the same whether subjects had been subjected to passive warm-up or whether they had run without warm-up.

TABLE 2

SIGNIFICANT DIFFERENCES IN PARAMETERS EXCEEDING THE .01, .02, OR .05 LEVEL OF SIGNIFICANCE

Variables	Min	M^1	M^2	Diff	t	Level
Respiration Recovery	2	20.60	22.28	1.68	2.32	.02
	3	19.30	20.33	1.03	2.34	.02
O_2 Uptake l/m Running	2	2.34	2.51	.17	2.10	.05
	5	3.46	3.65	.19	2.52	.02
O_2 Uptake l/min/M^2BSA Running	3	1.58	1.60	.02	2.64	.02
	5	1.93	1.86	.07	3.08	.01
CO_2 Expired l/min/M^2BSA Running	5	1.55	1.63	.08	2.80	.01
Ventilation l/min Pre-Exercise		13.20	12.80	.40	2.10	.05
Ventilation l/min/M^2BSA Pre-Exercise		6.91	6.46	.45	2.18	.05
Running	4	37.00	38.15	2.51	2.51	.02

M^1 = non-warm condition
M^2 = warm condition

TABLE 3

MEANS, STANDARD DEVIATIONS, MEAN INCREASE, PER CENT INCREASE, RECOVERY, AND PER CENT HEART RATE RECOVERED

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	65.25	130.50	138.75	146.75	147.50	150.66
S.D.	13.27	19.23	19.52	16.38	21.34	21.93
Mean Increase		65.25	73.50	81.50	82.25	85.41
Per Cent Increase		100.00	112.64	124.90	126.05	130.89
		Recovery				
Means		102.50	87.60	80.25	78.50	76.75
S.C.		16.20	14.22	14.34	12.51	13.59
Recovery		37.25	22.35	15.00	13.25	11.50
Per Cent Recovery		63.67	74.49	81.31	83.12	85.02
Warm-Up		Running				
Means	65.80	135.25	142.25	143.25	151.75	156.00
S.D.	12.03	23.12	22.22	21.11	21.08	19.63
Mean Increase		69.45	76.45	77.45	85.95	90.20
Per Cent Increase		105.55	116.18	117.71	130.62	137.08
		Recovery				
Means		101.75	84.05	80.00	77.45	75.60
S.D.		14.17	9.11	8.69	8.91	8.90
Recovery		35.95	18.25	14.20	11.65	9.80
Per Cent Recovery		64.67	77.79	81.25	84.96	87.04

TABLE 4

MEANS AND STANDARD DEVIATIONS OF RESPIRATION DURING TESTS

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	16.00	26.22	30.05	34.13	33.74	35.89
S.D.	4.20	7.65	6.01	6.91	7.30	6.81
		Recovery				
Means		24.20	20.60**	19.30**	20.00	18.90
S.D.		6.15	7.14	5.84	6.02	6.17
Warm-Up		Running				
Means	15.80	24.23	29.91	34.16	34.53	35.84
S.D.	4.50	4.47	5.22	6.88	5.73	6.75
		Recovery				
Means		25.80	22.28	20.33	19.83	19.40
S.D.		6.66	5.81	5.14	5.56	5.50

*.01 level
**.02 level
***.05 level

TABLE 5

MEANS AND STANDARD DEVIATIONS OF OXYGEN UPTAKE
IN LITERS/MINUTE

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	.35	1.23	2.34***	3.00	3.21	3.46**
S.D.	.68	.19	.36	.45	.51	.54
		Recovery				
Means		2.33	1.29	.80	.67	.56
S.D.		.52	.32	.21	.14	.09
Warm-Up		Running				
Means	.35	1.32	2.51	3.17	3.46	3.65
S.D.	.51	.41	.42	.47	.68	.59
		Recovery				
Means		2.46	1.26	.85	.66	.56
S.D.		.46	.28	.22	.13	.13

*.01 level
**.02 level
***.05 level

The mean pre-exercise oxygen uptake in liters/minute/M^2 body surface area was 0.18 liters prior to running in the cold condition. For the first minute of running the oxygen uptake liters/minute/M^2BSA was 0.60 liters reaching a peak of 1.93 liters at the fifth minute of running. Prior to the warm condition, the mean pre-exercise oxygen uptake in liters/minute/M^2BSA was 0.21 increasing to 0.71 at the first minute of running and reaching a peak of 1.86 liters at the fifth minute of running (Table 6). Following passive warm-up the oxygen uptake liters/minute/M^2BSA was significantly larger (.02 level) during the third minute of running than when subjects had not warmed up. However, during the fifth minute of running the oxygen uptake liters/M^2BSA was significantly larger when subjects had not warmed up than when they had undergone passive warm-up (.01 level), see Table 2.

Following running in the cold condition the mean oxygen uptake in liters/minute/M^2 body surface area for the first minute of recovery was 1.26 dropping to the lowest mean (0.28 liters) at the fifth minute of recovery. For the first minute of recovery, the mean oxygen uptake in liters/minute/M^2 body surface area following running after passive warm-up was 1.27, reaching its lowest uptake of 0.28 at the fifth minute. (See Table 6.)

Prior to running in the cold condition the mean expired carbon dioxide in liters/minute/M^2 body surface area was 0.17, increasing to 0.56 during the first minute of running and reaching a peak of 1.55 liters at the fifth minute. While in the warm condition

TABLE 6

MEANS AND STANDARD DEVIATIONS OF OXYGEN UPTAKE IN LITERS/MINUTE/METERS SQUARED BODY SURFACE AREA

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	.18	.60	1.23	1.58**	1.66	1.93
S.D.	.04	.11	.19	.18	.20	.23
		Recovery				
Means		1.26	.67	.42	.35	.28
S.D.		.28	.15	.10	.07	.04
Warm-Up		Running				
Means	.21	.71	1.28	1.60	1.64	1.86*
S.D.	.03	.21	.17	.21	.27	.21
		Recovery				
Means		1.27	.65	.44	.34	.28
S.D.		.19	.11	.09	.06	.06

*.01 level
**.02 level
***.05 level

the mean pre-exercise expired carbon dioxide was 0.16 liters/minute/M^2 body surface area. It increased to 0.58 during the first minute and reached a peak of 1.63 at the fifth minute of running (see Table 7). The only significant difference between means while running following passive warm-up and running without warm-up was at the .01 level during the fifth minute (see Table 2).

The means and standard deviations for expired carbon dioxide in liters/minute/M^2BSA for the recovery periods are shown in Table 7. For the first minute of recovery following running in the cold condition the mean was 1.16 liters--dropping to the lowest point (0.13 liters) at the fifth minute. During the first minute of running following passive warm-up the mean liters expired CO_2/M^2 body surface area was 1.15 reaching the lowest point of 0.30 liters at the fifth minute. There were no significant differences in the mean during recovery.

The means for both ventilation in liters/minute and liters/minute/M^2BSA were significantly larger (.05 level) prior to running in the cold condition than was the case prior to running following passive warm-up. (See Table 2.) At this point it must be remembered that the pre-exercise data were secured prior to running in the cold condition and being exposed to the passive warm-up. For some unexplainable reason, one subject had a much higher ventilation rate during one pre-exercise period, possibly, which caused the significant difference between the test-data for the two conditions.

TABLE 7

MEANS AND STANDARD DEVIATIONS OF CARBON DIOXIDE EXPIRED IN LITERS/MINUTE/METER SQUARED BODY SURFACE AREA

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	.17	.56	1.02	1.31	1.48	1.55
S.D.	.03	.10	.20	.22	.23	.27
		Recovery				
Means		1.16	.75	.44	.39	.31
S.D.		.29	.25	.12	.10	.07
Warm-Up		Running				
Means	.16	.58	1.05	1.34	1.50	1.63*
S.D.	.03	.17	.17	.24	.28	.28
		Recovery				
Means		1.15	.65	.46	.37	.30
S.D.		.24	.15	.12	.08	.08

*.01 level
**.02 level
***.05 level

For the first minute of running with no warm-up the mean ventilation in liters/minute was 39.50 reaching a peak of 76.60 liters/minute at the fifth minute. The mean for the first minute of running following passive warm-up was 40.62 liters with a rise to 77.85 liters at the fifth minute. (See Table 8.) The means following warm-up and those with no warm-up were not significantly different.

During recovery no significant t-values resulted from the differences between the means.

For the first minute of running while in the cold condition the mean ventilation in liters/minute/m_2BSA was 20.35 liters/minute reaching a peak of 39.43 liters at the fifth minute. The mean for the first minute of running following passive warm-up was 22.07 liters with a rise to 40.45 liters at the fifth minute of running. (See Table 9.) The only significant difference in means (.02 level) while running following passive and with no warm-up was during the fourth minute of running. (See Table 2.)

During recovery no significant t-values were found from the differences between the means.

TABLE 8

MEANS AND STANDARD DEVIATIONS OF VENTILATION IN LITERS/MINUTE

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	13.20***	39.50	60.50	69.90	72.60	76.60
S.D.	2.32	7.14	11.39	11.25	13.08	14.42
		Recovery				
Means		55.25	32.90	23.80	22.30	19.30
S.D.		13.83	9.28	6.66	5.23	4.50
Warm-Up		Running				
Means	12.80	40.62	61.40	70.75	72.59	77.85
S.D.	1.98	10.79	8.88	11.54	13.08	12.67
		Recovery				
Means		52.62	32.10	25.94	22.00	19.25
S.D.		10.41	6.80	5.63	4.50	4.67

*.01 level
**.02 level
***.05 level

TABLE 9

MEANS AND STANDARD DEVIATIONS OF VENTILATION IN LITERS/MINUTE/METER SQUARED BODY SURFACE AREA

	Av. Pre-Ex. (Sitting)	1 Min	2 Min	3 Min	4 Min	5 Min
Non-Warm-Up		Running				
Means	6.91***	20.35	30.88	35.80	37.00	39.43
S.D.	1.19	3.64	5.24	5.11	5.20	6.23
		Recovery				
Means		28.20	16.10	12.05	11.60	9.80
S.D.		6.27	3.94	2.98	2.79	2.13
Warm-Up		Running				
Means	6.46	22.07	31.60	36.25	38.15**	40.45
S.D.	.97	5.00	3.69	5.24	5.43	4.83
		Recovery				
Means		27.45	16.15	12.80	11.40	9.03
S.D.		4.58	2.95	2.61	2.08	2.15

*.01 level
**.02 level
***.05 level

CHAPTER V

DISCUSSION

The well-regulated athletic program places a considerable amount of stress upon warm-up. There is however, little agreement among athletic coaches and athletes as to the extent of warm-up. It is assumed that if warming up is important, there will be measurable physiologic differences in the warmed- versus the unwarmed-up individual.

There is, as mentioned earlier, relatively extensive literature on warm-up versus no warm-up as related to physical performance. There is no uniform agreement as to the findings. Several investigators have reported that performance was improved by a warm-up (2, 3, 10, 11) while other investigators have reported that a warm-up prior to testing did not significantly improve performance (5, 6, 7, 9, 13, 14).

Relative to differences in physiologic responses, two studies were reviewed. Howard, Blyth and Thorten (5) found no statistically significant differences between the maximum heart rates of exercise performed with and without a warm-up.

Unpublished data secured by Elbel and Mikols (4) relative to the effects of passive warm-up versus active warm-up showed that the mean heart rates during running and recovery did not differ significantly whether the subjects had warmed passively or actively.

While these investigators found that the mean number of respirations per minute were larger from the first minute of running through the tenth minute of recovery, the mean differences produced t-values significantly different for the first, eighth and ninth minutes of running only. On the other hand, their data showed significantly larger means for ventilation from the third through the ninth minute of running and for the fourth minute of recovery. No such differences were obtained for the above variables within the limits of the present study.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Ten male university students were used as subjects for the purpose of obtaining the data for this study. The subjects followed the same procedure on each of five consecutive days. One day was given over for instruction. On each of two days the subjects ran on a treadmill following passive warm-up, and on each of two other days the running was done without warm-up.

The order of testing of subjects was randomized, but subjects performed in the warm condition and the cold condition on alternate days. At the end of the fifth day the testing cycle was completed.

Means and standard deviations were determined for heart rate, oxygen uptake, carbon dioxide expired, respirations/minute, and total ventilation.

The t-values were computed to determine possible significant differences between the means for the two tests. For this study only those "t" values significant at .01, .02 or .05 level were considered.

Conclusions

On the basis of the data it was concluded that:

1. Based upon the significantly smaller means for respirations per minute, recovery was significantly greater for

the second and third minutes after running with no warm-up than running following passive warm-up.

2. Based upon t-value, the mean oxygen uptake in liters/minute was significantly greater for the second (.05 level) and the fifth (.02 level) minutes of running following passive warm-up.

3. Following passive warm-up the mean oxygen uptake in liters/minute/M^2BSA was significantly larger (.02 level) during the third minute of running. However during the fifth minute of running the oxygen uptake in liter/minute/M^2BSA was significantly larger when subjects had not warmed up (.01 level).

4. The only significant difference in the mean carbon dioxide expired in liters/minute/M^2BSA was found at the fifth minute of running following passive warm-up (.01 level).

5. The means for both ventilation in liters/minute and liters/minute/M^2BSA were significantly larger (.05 level) prior to running in the cold condition.

6. It was found that the means for ventilation in liters/minute/M^2BSA were significantly greater (.02 level) for the fourth minute of running following passive warm-up.

Because of the lack of consistency in significant mean differences, it is concluded that passive warm-up affected the physiological parameters during vigorous performance no differently than did no warm-up.

Recommendations

Since the results of the present study were not conclusive, it is recommended that additional research be conducted toward determining whether statistically significant differences result in physiologic measures during and following strenuous physical exercise under the following conditions:

1. When the activity is done without prior warm-up.
2. When the individual has been warmed passively.
3. When the subject has warmed up actively.

BIBLIOGRAPHY

1. Benjamin, F. B. and Peyser, L. Physiological effects of active and passive exercise. J. Applied Physiol. 19:1212-14, Nov. 1964.

2. Carlile, F. Effect of preliminary passive warming on swimming performance. Res. Quart. 27:143, 1956.

3. DeVries, H. A. Effects of various warm-up procedures on 100 yd. time of competitive swimmers. Res. Quart. 30:11-20, 1959.

4. Elbel, E. R. and Mikols, W. J. Univ. of Kansas. Unpublished data on Athletic Warm-up, 1962.

5. Howard, G., Blyth, C., and Thorten, W. The effects of warm-up on the heart rate during exercise. Res. Quart. 37:360-67, 1966.

6. Karpovich, P. V. and Hale, C. Effect of warming-up upon physical performance. Journal Am. Med. Assoc., 162:1117-19, 1956.

7. Lotter, Willard S. Effect of fatigue and warm-up on speed of arm movement. Res. Quart. 30:57-65, 1959.

8. Massey, B. H., Johnson, W. R., and Kramer, G. F. Effect of warm-up exercise upon muscular performance using hypnosis to control psychological variable. Res. Quart. 32:63-71, 1961.

9. Mathews, D. K. and Snyder, H. A. Effect of warm-up on the 440-yd dash. Res. Quart. 30:446-51, 1959.

10. Michael, E., Skubic, V., and Rochelle, R. The effect of warm-up on softball throw for distance. Res. Quart. 28:357-63, 1957.

11. Pacheco, B. Improvement in jumping performance due to preliminary exercise. Res. Quart. 28:55-63, 1957.

12. Robbins, A. C. Effects of hot and cold showers upon adolescents participating in physical education classes. Res. Quart. 13:373-80, 1942.

13. Sedgwick, A. W. and Whalen, H. R. Effect of Passive Warm-up on muscular strength and endurance. Res. Quart. 35:45-59, 1964.

14. Skubic, V. and Hodgkins, J. Effect of warm-up activities on speed, strength, and accuracy. Res. Quart. 28:147-52, 1957.

15. Smith, J. and Bozymowski, M. The effect of attitude toward warm-up on physiological performance. Res. Quart. 36:78-85, 1965.

16. Thompson, H. The effects of warm-up on performance in selected activities. Res. Quart. 29:231-46, 1958.